southeastward attended by marked changes in temperature from the middle-eastern and northeastern slopes of the Rocky Mountains over the Missouri and upper Mississippi valleys and Lake Region. When a high area appears on the North Pacific Coast, and the low area is located over or east of the Great Lakes, a secondary disturbance generally develops over the central valleys. If a high area appears on the North Pacific Coast and a low area is not shown in the Northwest, one will probably develop within twelve hours.

The Pacific Coast high areas of September advance to the upper Mississippi Valley in about seventy-two hours at an average velocity of about 21 statute miles per hour. During that period the low areas which appear in the Northwest pass eastward over the northern Lakes and reach Newfoundland traveling at an average velocity of 28 miles per hour. In September, when the pressure rises above 30.20 on the North Pacific Coast and falls below 29.80 between Lake Superior and the upper Missouri Valley, rain may be expected within an area extended from the western Lakes over the extreme upper Mississippi Valley in twenty-four hours; over the middle, southern, and eastern Lake Region in thirty-six hours; and over New York, northeastern Pennsylvania, northern New Jersey, and New England in forty-eight hours. A temperature fall of 10° or more will probably be experienced on the northeast slope of the Rocky Mountains and over the western half of the Dakotas in twenty-four hours; from the eastern half of the Dakotas over the extreme upper Mississippi Valley and western Lake Superior in thirty-six hours; and over the Lake Region in forty-eight hours. Occasionally a September high area will appear on the North Pacific Coast showing pressure above 30.20, with a rather weak low area over or north of the upper Missouri Valley. The high area will remain nearly stationary for a period of one, two, or three days, with increasing pressure, and the low area will gradually deepen. When the low has gathered sufficient strength to overcome the obstruction (generally a high area to the eastward) which has prevented its eastward advance the eastward movements of the high and low areas begin. In such cases the low area generally increases in intensity as it passes over the Great Lakes. Again, a deep low area will appear in the Northwest and remain nearly stationary for several days, while the pressure gradually increases over the North Pacific Coast Region. When the pressure on the North Pacific Coast reaches 30.20 an eastward movement of the high and low areas may be expected. In cases where the pressure does not rise to 30.20 on the North Pacific Coast the low area in the Northwest will dissipate.

In October the movements of the high and low areas are somewhat more rapid than for the preceding month. The high areas from the North Pacific Coast advance to the middle Ohio Valley in seventy-two hours and the low areas traverse a path extending from the one hundredth meridian to a point southeast of Newfoundland in the same period of time. In October, when the pressure rises to 30.20 or above on the North Pacific Coast and falls to or below 28.80 in the Northwest, rain or snow may be expected over the Red River of the North Valley, over the extreme upper Mississippi Valley, and the northwestern Lake Region in twenty-four hours; in the Lake Region and upper Mississippi and northern Ohio valleys in thirty-six hours, and in the Middle Atlantic and New England States in forty-eight hours. The temperature will probably fall 10° or more in the middle and upper Missouri valleys in twenty-four hours; over the Red River of the North Valley, over the extreme upper Mississippi Valley and the western Lake Region in thirty-six hours, and over the central and eastern Lake Region and the interior of Pennsylvania, New York, and New England in forty-eight hours.

In November there is a marked change in the character of the high areas that appear over the northwestern part of the United States. In that month a majority of the high areas advance from the British Northwest Territory and enter the region of observation on the northeast slope of the Rocky Mountains. The high areas that advance from the North Pacific Coast often settle southeastward and become a part of the permanent high that commences to build up over the middle plateau region with the advent of the colder months. Many of the high areas that appear over the British Northwest Territory show pressure above 30.50 and sometimes 30.70 and 30.80. High areas of this class often extend westward over the North Pacific Coast. This class of high areas is not considered in the present paper.

In November, when a high area appears on the North Pacific Coast with a low area east of the ninetieth meridian, rain or snow will probably fall in New England within twenty-four hours. When high areas advance from the British Northwest Territory the preceding low areas are seldom attended by precipitation west of the Great Lakes. When the pressure on the North Pacific Coast rises to or above 30.30 and falls to or below 29.80 in the Northwest, precipitation may be expected in the middle and upper Missouri and extreme upper Mississippi valleys and the upper Lake Region in twenty-four hours; in the lower Lake Region, New York, and northern Pennsylvania in thirty-six hours, and from the eastern Lakes over the Middle Atlantic and New England States in forty-eight hours. The temperature will probably fall 10° or more over the Missouri Valley, and the extreme upper Mississippi Valley, in twenty-four hours; in the upper Lake Region and the upper Mississippi and lower Ohio valleys in thirty-six hours, and from the lower Lake Region over the interior of the Middle Atlantic and New England States in forty-eight hours.

[Note.—Three charts, Nos. VI, VII, and VIII, accompanied the preceding article and are reproduced herewith.]

SPECIAL CONTRIBUTIONS.

THE MARVIN SEISMOGRAPH.

By Prof. C. F. Marvin, U. S. Weather Bureau.

A seismograph is an instrument that produces an automatic record of tremblings, oscillations, vibrations, or quakings of the crust of the earth. In the most complete seismograph the precise time at which the event takes place and the exact nature and extent of the motions of the earth particle, that is, the portion of the surface supporting the instrument, are all faithfully recorded, but the name is also frequently and properly applied to instruments that record perhaps no more than one of the elements mentioned above, or even simply the time of occurrence of the tremors.

The rumbling of a cart or wagon along a roughly paved roadway near at hand, the passage of a train at a distance, or a remote and violent explosion, all produce tremors in the earth that differ from actual earthquakes, properly so-called, in intensity and violence. With little difficulty instruments can be constructed that will faithfully record even the feeblest of these tremblings.

Small seismic disturbances, or earthquakes, are frequent even in the eastern portion of the United States, and geologists are interested in the systematic observation of such phenomena. The very considerable cost and the great delicacy of instruments for automatically registering all the features of earth tremors, together with the technical skill required for their management, and the prolonged periods throughout which they must be maintained in constant readiness for the infrequent disturbances, constitute a series of obstacles that have quite prevented the installation and maintenance of many such instruments. Whenever a large seismic disturbance does occur, however, the need of accurate records of the phenomena and the complete lack of instrumental measurements are strongly felt on every side.

This was the case in the month of November, 1892, at which time violent explosions of dynamite and other material were made near the city of Washington, with the object of artificially producing rain, if possible. The complete lack at the Weather Bureau of any record of possible earth tremors caused by those explosions led the Chief of the Bureau to authorize the installation of the seismograph described below.

Before taking up this description, however, it is desired to analyze somewhat superficially, perhaps, earthquake action, and show the value and use of earthquake observations.

Our experience teaches us that seismic actions generally, if not always, begin with quite imperceptible tremors, which increase rapidly in intensity, and, after passing the period of greatest violence, die out as imperceptible tremors.

Any instrument designed to be influenced by disturbances of this character will always have a certain limit of sensitiveness and will not be affected until the tremors attain some intensity. Tremors of very feeble intensity may be registered by photographic means, whereas, disturbances of relatively greater intensity are necessary to set in action those instruments which register by mechanical appliances, such as the marking of a pen on a sheet of paper.

Probably the most sensitive form of seismograph capable of recording simply the time of occurrence of an earthquake would consist of devices by which a fixed beam of light is made to produce a trace on a photographic plate moved by clockwork. If the light first undergoes reflection from a surface of clean mercury contained in a vessel firmly imbedded in the earth, then the slightest earth tremors would break up the mercury surface into minute wavelets, and so alter the direction of the reflected ray of light as to make a break in the continuity of the photographic trace. The time of the beginning of the gap in the trace would mark the beginning of the earthquake, and the length of the gap would mark the duration of the disturbance—at least approximately, for, in considering such a record, we need to bear in mind that the mercurial surface once disturbed would continue in motion for several seconds after the actual earth tremors had ceased. Some allowance for this could probably be made.

The next point to consider is the value and significance of a precise record that shows only the time of occurrence of an earthquake.

A single record at one point only of the time of beginning of a disturbance does not possess much value, but a number of unformly accurate records over a large region may be made to give indications of the locality in which the earthquake had its origin. The rate of progression of the earth wave across the country and through rocks and soils of different characters may also be determined. To set forth more clearly how this is done suppose, for example, that the greater part of the stations of the Weather Bureau, distributed as they are, far and wide over the United States, were each equipped with a seismograph from which could be determined the exact time of occurrence and duration of an earthquake at the station in question. Suppose, for example, the origin of some earthquake was in the vicinity of Lake Michigan. It is plain that the seismographs all around this locality and near to it would record the time earliest, while those farther and farther away would show the time to have been later and later. By charting the observations thus made and drawing isochronic lines not only would the general origin of the disturbance and its speed of travel be indicated but much more, that is now perhaps little imagined, could be learned in regard to earthquakes. In studying such records we would need, among many other refined details, to consider that at the most distant points the record would have reference to the most violent portion of the real disturbance, for the reason that the feebler portions that were yet powerful enough to set off the seismographs at moderate distances would not, perhaps, reach the more remote regions. If from the records we could form also some idea of the duration of the shock, or better, its intensity at different instants, their value would be much enhanced.

With these brief general remarks we will pass to a description of the seismograph which has been maintained in continuous operation at the Weather Bureau since the winter of 1892-3. Recognizing that a single record in a vast region could not be of great utility no special effort was made to secure in this particular seismograph either a very high degree of sensitiveness or the greatest precision of time measurement.

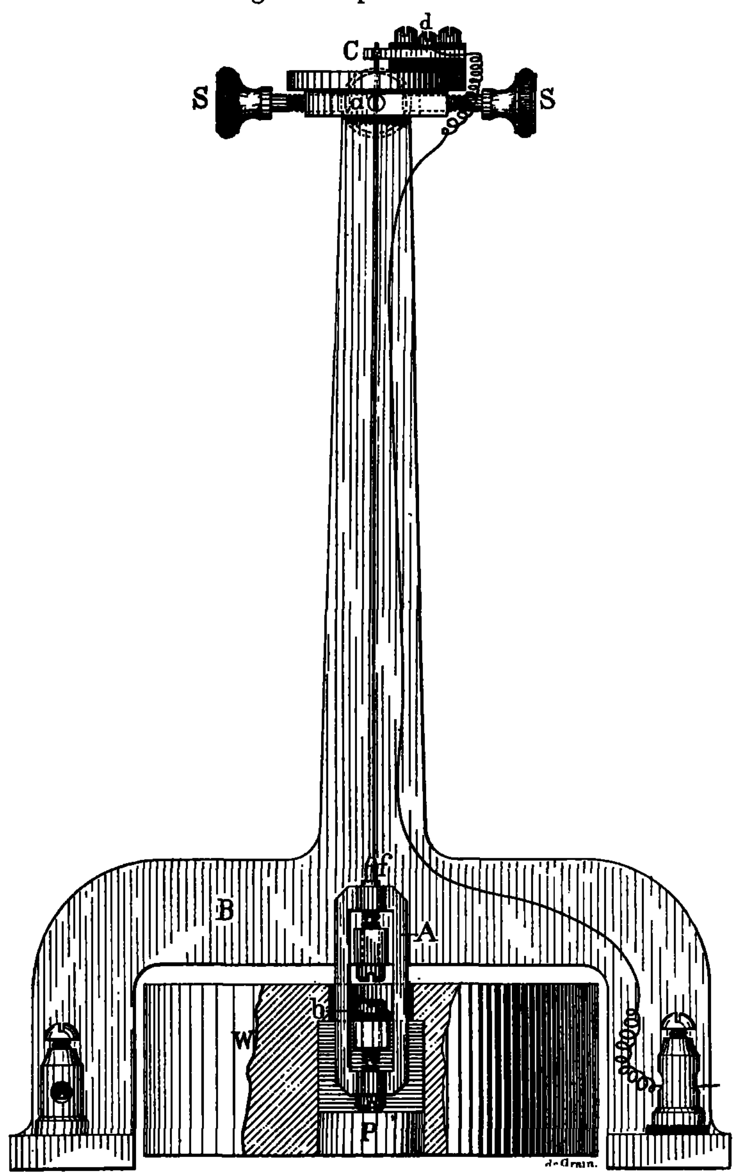

FIG. 1.—The Marvin seismograph.

The instrument was designed to be as simple as possible and to record only the time of beginning of the disturbance. Some idea of the duration of the earthquake is also given, but not very accurately. The record is made on a scale of

$2\frac{1}{2}$ inches per hour, which enables the time of an event to be measured to within from fifteen to thirty seconds. That the instrument is sufficiently sensitive and reliable is shown by the fact that except when being tested no record has thus far been obtained except for real earthquakes.

The instrument is a modification of a form devised by the writer early in 1885, as is shown in Fig. 1.

W is a heavy lead weight, shown partly in section, and is suspended on a short steel link, *A*. The weight is pivoted to this link by means of the sharp pointed screw, *b*, the point being just above the center of gravity of the weight, so that the latter will balance and remain stable on the pointed support. A similar pointed support, *f*, is provided for the top of the link, which hangs from a small projection from the frame of the instrument, *B*. The pin, *f*, is extended upward from the link, being in all about 6 inches long, and is made slender and flexible. At the top the needle-like prolongation of the link, *A*, is tipped with platinum, and passes loosely through a small hole in the plate, marked *C*. The hole in the plate is bushed with platinum; four screws, two of which, *S*, *S*, are shown, enable one to adjust the position of the plate, so that the platinum-tipped needle will pass through the center of the hole and not touch it on any side. The plate, *C*, is electrically insulated from the rest of the instrument, but connected with a wire to a binding post on the base.

The action of the instrument is easily understood. Any movement of the base or frame of the instrument affects the point from which the link, *A*, is suspended. The heavy weight, *W*, does not partake of this motion, but tends to remain at rest; the result is that the link is displaced from the vertical a little, and the motion is greatly magnified at the top end of the long needle-like extension. Supposing the needle to be originally set so as not to touch the sides of the hole in the plate, *C*, it is plain that a disturbance will cause it to repeatedly strike the sides of the hole, and, when the instrument is appropriately connected with batteries and electrical apparatus, the contact of the needle with the sides of the hole can be made to stop a clock or to produce an automatic record on a sheet of paper.

The register used with the Weather Bureau seismograph is simply a so-called weekly anemometer register, and is shown in Fig. 2.

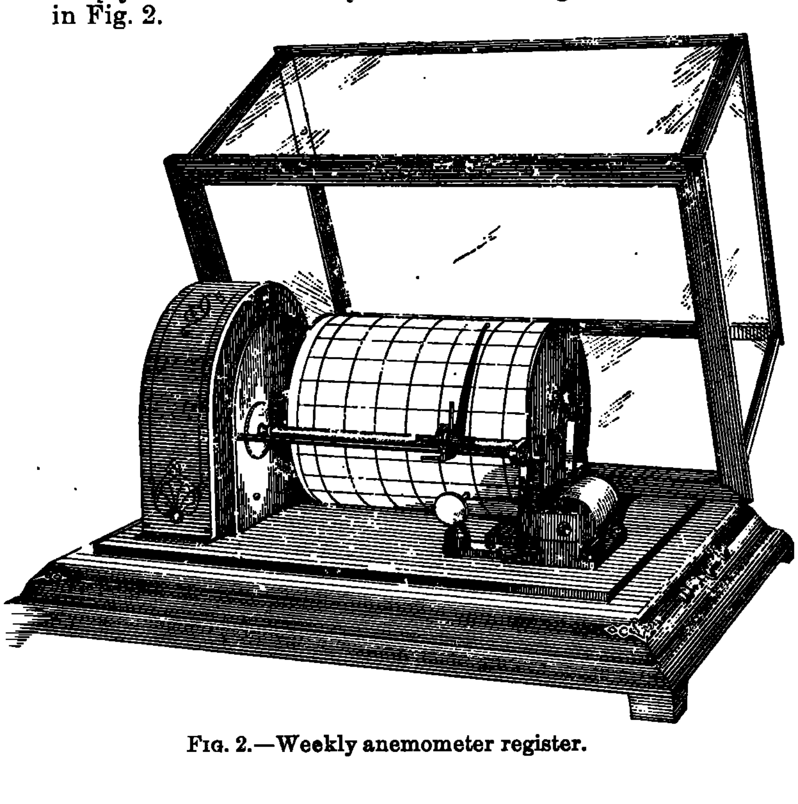

FIG. 2.—Weekly anemometer register.

The cylinder of this register revolves once in six hours, and the pen is so controlled as to trace a spiral line on the sheet which receives the record for seven days without changing. The electro-magnet seen on the base of the instrument is connected with the seismograph, and whenever the circuit is closed the pen makes a jog or offset in the line traced. The sheet of paper is marked off with hour lines and finer spaces of five minutes each, so that the time of any event marked by the offsets in the trace made by the pen can be accurately measured. A minute of time is represented by a space of one twenty-fourth of an inch on the sheet. As the clock which drives the cylinder can not be depended upon to keep time accurately, the electro-magnet is also connected with a good pendulum clock fitted with a device which momentarily closes the circuit at intervals of exactly five minutes to the nearest second. Finally, the error of the pendulum clock is obtained and recorded almost daily from the telegraphic time signals sent out by the Naval Observatory.

The record of an earthquake consists of a succession, more or less prolonged, of lateral jogs or strokes on the line traced by the pen, whereas the clock record consists of a single stroke occurring regularly and of very short duration.

The apparatus thus described requires very little attention to maintain in operation. The time scale of the record is greatly condensed, but less than half a minute of time can be discerned.

The seismograph is mounted on a stone slab cemented to the floor of the basement of the Weather Bureau building. It does not appear to be disturbed by the ordinary tremors due to artificial causes.

TORNADOES AT CHERRY HILL, N. J., AND WOODHAVEN, LONG ISLAND, N. Y.

Text by Mr. E. H. EMERY; photographs* by Mr. H. GOUCHER, Assistants at the Weather Bureau station, New York, N. Y.; dated August 21, 1895.

In the afternoon of July 13, 1895, there occurred in northeastern New Jersey, western end of Manhattan Island, and western portion of Long Island a series of atmospheric disturbances, partaking of the nature of severe wind and hail storms in some places, and in others of tornadic movements. From Atlantic Highlands to Cape May thunderstorms, with hail and high winds, prevailed, damaging crops and fruit trees. At Cherry Hill, N. J., and Woodhaven, L. I., the storms were tornadic in their chief phases and usual effects. Cherry Hill is distant north of Hackensack, N. J., $1\frac{1}{2}$ miles, and northwest of Harlem, N. Y., 11 miles. Harlem is $11\frac{1}{2}$ miles northwest of Woodhaven. The path of the storm was in a southeasterly direction, passing over Harlem, N. Y., thence to Woodhaven. [Woodhaven is about 8 miles east-northeast of the Weather Bureau station in New York City.]

At Cherry Hill the storm commenced its destructive work. Four dwellings and a depot were destroyed and 26 other buildings partly shattered. Amount of damage estimated at $50,000. Three persons were killed. About 3.30 p. m. black clouds were observed coming from the northwest; it was 3.45 p. m. when the storm broke out, and five minutes later came the destructive wind.

At nearly the same time that buildings were being blown down at Cherry Hill a severe wind and hail storm was raging in that portion of New York called Harlem, between One hundred and twenty-fifth street and Woodlawn Cemetery, East River and Kings Bridge, continuing for twenty minutes. Here the storm had nothing of the tornado about it. From this point the disturbance passed on to one of the suburbs of Brooklyn, which is southeast of Harlem. The destruction by violent winds began at Cypress Hills Cemetery. As observed by an eye witness, there seemed to be a meeting of two large black masses of clouds, one coming from the north-

*The photographs are not reproduced.